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## **Impact of World War 1 on placenta weight, birth weight and other anthropometric parameters of neonatal health**

Butie, Claire ; Matthes, Katarina L ; Hösli, Irene ; Floris, Joël ; Staub, Kaspar

**Abstract:** Background Wars do not only affect combatant countries, populations in neutral zones can be afflicted by circumjacent conflicts as well, posing a great health burden on mothers and newborns. As neonatal health remains an ongoing cause for concern, identifying determinants that impede fetal growth is crucial. Under this pretext, the study aimed to analyze the impact of World War 1 in the neutral city of Basel on neonatal health by assessing changes in anthropometric parameters. Methods A retrospective analysis of yearly cross sections of term births in the maternity hospital of Basel from 1912 to 1923 was conducted (n = 3718). We tested adjusted anthropometry for time trends in comparison to a pre-war baseline, including birth weight, placenta weight, birth length, ponderal index and gestational age. Interrelations of placenta weights and birth weights were examined separately through birth weight to placenta weight (bw/pw) ratios and residuals of placenta weight to birth weight regressions. Results Birth weights, placenta weights and residuals were at their lowest in 1918/19, a trend not reflected in bw/pw ratios. Birth lengths remained low while ponderal indexes declined during the entire period of war, gestational age remained rather stable. Discussion 1918/19 were the pinnacle years for the population of Basel, who were suffering from general detrimental economic conditions, a food supply crisis and an outbreak of the Spanish Flu. These adverse circumstances coincided with low birth and placenta weights, residuals depicting the correlation of birth weights to placental weights more closely than bw/pw ratios.

DOI: <https://doi.org/10.1016/j.placenta.2020.07.003>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-188498>

Journal Article

Published Version



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Originally published at:

Butie, Claire; Matthes, Katarina L; Hösli, Irene; Floris, Joël; Staub, Kaspar (2020). Impact of World War 1 on placenta weight, birth weight and other anthropometric parameters of neonatal health. *Placenta*, 100:150-158.

DOI: <https://doi.org/10.1016/j.placenta.2020.07.003>

# Journal Pre-proof

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PII: S0143-4004(20)30193-4

DOI: <https://doi.org/10.1016/j.placenta.2020.07.003>

Reference: YPLAC 4184

To appear in: *Placenta*

Received Date: 5 February 2020

Revised Date: 3 July 2020

Accepted Date: 6 July 2020

Please cite this article as: Butie C, Matthes KL, Hösli I, Floris Joë, Staub K, Impact of World War 1 on placenta weight, birth weight and other anthropometric parameters of neonatal health, *Placenta* (2020), doi: <https://doi.org/10.1016/j.placenta.2020.07.003>.

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# Impact of World War 1 on Placenta Weight, Birth Weight and other Anthropometric Parameters of Neonatal Health

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## Keywords:

Newborns, Time Trends, Living Standards, Anthropometric History

## Highlights

- A retrospective analysis of term births in the maternity hospital of Basel from 1912 to 1923 was conducted.
- Birth weights, placenta weights and residuals were at their lowest at the end of the war in 1918/19.
- Populations in neutral zones during wars can be afflicted as well, posing a great health burden on mothers and newborns.

**Abstract**

*Background:* Wars do not only affect combatant countries, populations in neutral zones can be afflicted by circumjacent conflicts as well, posing a great health burden on mothers and newborns. As neonatal health remains an ongoing cause for concern, identifying determinants that impede fetal growth is crucial. Under this pretext, the study aimed to analyze the impact of World War 1 in the neutral city of Basel on neonatal health by assessing changes in anthropometric parameters.

*Methods:* A retrospective analysis of yearly cross sections of term births in the maternity hospital of Basel from 1912 to 1923 was conducted ( $n = 3718$ ). We tested adjusted anthropometry for time trends in comparison to a pre-war baseline, including birth weight, placenta weight, birth length, ponderal index and gestational age. Interrelations of placenta weights and birth weights were examined separately through birth weight to placenta weight (bw/pw) ratios and residuals of placenta weight to birth weight regressions.

*Results* Birth weights, placenta weights and residuals were at their lowest in 1918/19, a trend not reflected in bw/pw ratios. Birth lengths remained low while ponderal indexes declined during the entire period of war, gestational age remained rather stable.

*Discussion:* 1918/19 were the pinnacle years for the population of Basel, who were suffering from general detrimental economic conditions, a food supply crisis and an outbreak of the Spanish Flu. These adverse circumstances coincided with low birth and placenta weights, residuals depicting the correlation of birth weights to placental weights more closely than bw/pw ratios.

## 1. Introduction

Neonatal health remains an ongoing cause for concern [1, 2]. Since the 1950s there have been significantly fewer deaths of children under 5 years of age [1]. However, there are still large regional differences around the world and the decline in deaths is greater among the post-neonatal groups than among neonates [1]. Overall, the proportion of deaths under 1 year within deaths under 5 years has increased [1]. In addition, the proportion of births below 2500 g is decreasing less rapidly than desired, with persisting regional differences around the world as well [2]. Thus, identifying determinants that impede normal development and growth are crucial to the cause of ameliorating neonatal health at large. An important tool for studying impaired (or excessive) fetal growth are anthropometric parameters of newborn infants [3]. They serve as a low-cost, non-invasive research method to record body size and proportion in both individuals and populations [4]. As indirect reference values, these parameters allow conclusions about the intrauterine environment, maternal nutrition and predictions of the newborns postnatal morbidity, mortality as well as long term health outcome [5-7].

The most common parameters in practice are birth weight (BW), head circumference (HC) and body length (BL), while BW and BL can be combined to a measure of body proportionality; Rohrer's Ponderal Index (PI) [3]. Placental weight (PW) is a further important perinatal parameter routinely recorded after delivery [8]. A positive correlation with BW has been repeatedly found [9-11], and the combination of BW and PW in form of a simple ratio (BW/PW ratio) has been implicated as a proxy of placental efficiency [12, 13]. All of these parameters vary in mean and spread values at different gestational ages (GA), therefore it is important to record the length of gestation in order for them to be validly compared [3, 14].

Neonatal body dimensions are determined by various factors, such as genetics of the fetus (e.g. sex, ethnicity [15]) and maternal characteristics, which include among others: age [16, 17], height [18], parity [19], pre-pregnancy weight and BMI [20, 21] as well as maternal social status [22], level of education [22], health (e.g. infection [23]) and lifestyle (e.g. cigarette smoking [19, 24]). Furthermore, it has been shown that maternal distress is associated with suppressed fetal growth [25]. Studies have further shown that maternal nutritional levels, especially third trimester exposure to malnutrition [26, 27], adversely affect fetal growth. Sufficient nutrition as well as access to adequate health care being dependent on the socio-economic environment during the pregnancy, recent studies have reported negative influences of economic downturns on neonatal health outcomes [28-30].

In the process of further assessing determinants influencing fluctuations of anthropometric parameters, a historical perspective may prove valuable, as it allows a retrospective examination of adverse perinatal environments on parameters of health and the possibility to monitor trends [31, 32]. The last time Switzerland's population experienced a severe downturn on a national economic and social scale was during the years of World War 1 (1914 – 1918). Although Switzerland remained neutral during the war, civilian welfare nevertheless suffered under the circumjacent political disruption: trade relations with belligerent countries thinned out [33], harvest failures in 1916 and 1917 led to a food rationing of staple foods in 1917 [34], and the outbreak of the Spanish Flu (1918/1919) further exacerbated the situation [35].

Basel is located where the Swiss, French and German borders meet, and the Western Front was in an immediate vicinity of the city. The city suffered under the disruption of normal trade relations caused by the war, which impacted Switzerland's economic and social situation seriously. Prices rose sharply due to inflation [36]. In the light of an impending undersupply, food rationing of staple foods was introduced in 1917 [34], and was kept in operation until its gradual resolution from 1919 to 1920 [34]. Real wages of skilled workers in Basel decreased and reached a minimum in the years 1918 and 1919 [37]. Additional emergency relief measures supported 30,000 people until the beginning of 1918 [36]. This was about a fifth of the population of Basel. The difficult social and economic situation was exacerbated by the outbreak of the Spanish flu in 1918. According to the health department roughly a quarter of the population of the city of Basel (35'000 cases) were infected by the virus and death toll rose to 732 deaths [35, 36, 38]. However, discharge began by 1919/20; the country had recovered to some extent and as the economy improved prices sank back toward pre-war levels and wages were on the rise again [33].

An earlier examination of births during World War 1 in the city of Basel revealed a decline in birth weight during the years 1918 and 1919 [33], which aligns with the findings of studies on the influence of economic downturns mentioned above [28-30]. However, all of these studies concentrated on birth weight (BW) as their main outcome factor. In World War 2, prenatal exposure to the Dutch famine of 1944-1945 caused a decline not only in BW, but also in PW, BL and HC [39]. Recent anthropometric historical studies further support the importance of multi-parameter investigations [40, 41]. Although the nutritional situation in the city of Basel was not as devastating for the population as it was during the Dutch famine in World War 2, or in other European countries affected by World War 1 (e.g. Russia [42]), the conditions were serious enough to have a negative effect on birth weight. Our goal therefore was to exhaust the same dataset for the city of Basel, and to expand the previously collected data by adding further anthropometric parameters of neonatal health in order to explore in turn how they reacted during the same time period (1912 – 1923).

We seek to contribute to the literature on the impact of perinatal exposure to political, social and economic crises in a war-time environment on a regional scale. In the following paper we will focus on term births in the city of Basel during the years 1912 – 1923 and address the following questions: What impact did World War 1 have on placenta weight, birth weight, birth weight in relation to placenta weight, body length and ponderal index? Were all of the selected parameters affected in the same way, or did they react differently?

## 2. Material and Method

### Data source

The individual data was extracted from the birth records of the university maternity hospital (Frauenspital) of the canton Basel Stadt (stored in the State Archive Basel Stadt), where childbirths have been recorded in detail since 1896. An individual record of birth spreads over four pages and contains precise information of the mother, the birth and the newborn. Incomplete records are very rare. For this paper, the inventory *Sanität X29* with 16 control books for the period from 1912 to 1923 was examined. Each book contains around 250 birth records. Since there was no admission selection, the maternity hospital was considered a cluster unit; mothers seeking medical assistance were not only from higher but also lower socioeconomic backgrounds and births ranged from problem-free to complicated. The vast majority of patients (> 85 %) were residents of the city of Basel, and this did not change during our observation period [33]. Regarding the years 1912 to 1923 approximately 50-66 % (overall 60%) of all childbirths (Appendix Table 1) and more than 90 % of all hospital childbirths per year in the city of Basel took place at the maternity hospital [33]. Thus, the number of childbirths occurring at the mothers home or in other hospitals were ca. 40% in the case of Basel, which was ca. 20% less than in Zurich during the same time [33].

However, the archived books – originally consisting of about three per year - constitute only about a third of the original full records and births given in the maternal hospital during our observational period (in the 1970s the archive reduced the number of books for storage reasons). As a result, our data inevitably represents only about 20% of all births in the maternity hospital Basel during this period, and thus about 16% of all births in the city of Basel (Appendix Table 1). There appeared to be no selection pattern - in particular no seasonal selection pattern - in the presently available books (see Appendix Table 1). The existing records of birth contain extensive and precise information, strongly suggesting a standardized method of data collection. Unfortunately, clarifications regarding the exact methods and protocols of measurement were not recorded (or those records may be lost).

Access to the protected individual data was allowed by the Staatsarchiv Basel-Stadt upon signed contractual agreement. After linking the sources and data cleaning, the data have been fully anonymized.

## Variables

The birth records contained numerous data concerning the mother, the birth and the newborn, only slightly restricting the variety of possible variables to be included in this study.

Birth weight (BW) is one of the most widely used anthropometric indicator of size, reflecting intrauterine development [3, 43]. Low birth weight ( $< 2500$  g) [44] is known to be a risk factor of morbidity and stunting in childhood [2], and has been identified to be associated with chronic diseases in adult life such as hypertension and non-insulin dependent diabetes [45]. Data has also shown that underweight women, in combination with malnutrition, have an increased risk of low birthweight infants [20, 23].

Birth length (BL) is another indicator of neonatal size, providing valuable additional information and proving to be a useful measure when birth weight is not available [3]. However, the reliability of this measure is not as high as for other parameters, owing to variations in posture and muscle tone of newborns and to interobserver errors, the measurement being sensitive to the training of the data collector [3]. BW and BL are often combined to Rohrer's ponderal Index ( $100 \times \text{BW in grams} / \text{cube of the birth length in cm}^3$ ), an index of proportionality. It may serve as an estimate of proportionate retardation or acceleration of growth in weight and length [3]. Newborn sex is known to stratify these indicators, as male neonates are by average heavier and taller with a larger head and chest circumference than females [27].

Placental weight (PW) is another important neonatal parameter, routinely recorded after birth. The placenta plays a crucial role in fetal growth, as dysfunctional placentas are correlated with low birth weight infants [46]. PW also reflects maternal body composition during pregnancy as a function of changing eating behaviors, for example during Ramadan [47]. As a proxy for placental efficiency, BW and PW have been combined to a ratio (BW/PW), defined as the grams of fetus produced per gram placenta [13]. Low ratios have been associated with asymmetric growth restriction in fetuses [48], high ratios with higher incidences of preeclampsia and intrauterine growth restriction [49]. A high ratio can also reflect a reduced placental volume, suboptimal placental function, reduced supply of nutrients and placental insufficiency [50]. However, a recent study advised a different statistical approach for measuring placental efficiency, as ratios have inherent properties that can lead to spurious results [51]. Changes in BW/PW ratios with placental size are a result of the fact that the intercept is not zero, meaning the ratio of BW/PW will change along the regression line [51]. This artifact of ratios may lead to interpretation errors, e.g. histologically immature placentas



at term appeared to be more “efficient” at birth according to the ratio [51]. Instead, the use of residuals of a regression of birth weight on placental weight is proposed. This method requires a sample of births and cannot be calculated for an individual birth, but it is less prone to artefacts [51]. We chose to include BW/PW ratio as well as residuals of regressions, in order to compare the results and examine their sensitivity to fluctuations of birth and placental weights. Size of the infant and of the placenta at birth not only reflects fetal growth but also duration of gestation [3]. BW/PW ratio at term is known to increase with GA, as the proportion of increase in BW is higher than PW [14, 48]. This corresponds to the association of small-for-gestational age infants and increased ratios due to increased placental size and decreased BW, which pose a risk factor of increased neonatal morbidity [52, 53]. In our data, GA was calculated as the difference between date of birth of the child and reported last menstruation of the mother.

In order to provide a context for the specific variables mentioned above, we examined the socio-economic environment of the mother through data that we gathered over the birth register (*inventory Sanität X8*) [33]. These registers were linked to the birth records in nearly 100 % of the cases. The co-factors examined included maternal age, height, parity and social status (married, unmarried) as well as the profession of the father (if known). A socioeconomic position (SEP) classification proposed by Schüren [33] was assigned to each occupation, the evaluated SEP for the father was then used to measure SEP of the family. The profession of the mother, although recorded, was not included in the SEP measure, except if the father was not recorded in the registers.

### Missing data

In order to handle missing values for height of mother (missingness 21.6%), GA (6.9%), PI (3.2%), birth length (3.2%), PW (1.8%), SEP (0.5%) and BW (0.1%) multiple imputation with chained equations (MICE) was applied to impute the incomplete data [54]. The imputation model includes the incomplete variables and the complete variables: year, age of mother, parity and sex [55]. Since the maximum fraction of missing information was approximately 21.6%, we created 22 complete datasets with 25 iterations [56, 57]. For each dataset, the analyses were performed separately and merged afterwards using Rubin’s rule [58]. We compared the results with a complete-case analysis [59]. The results of the multiple imputation and complete-cases analysis differ slightly but lead to the same conclusion. For that reason, only the results of the multiple imputation are shown in the main manuscript. The results of the complete-case analysis, however, can be found in the supplementary information (Appendix Figure 3).

### Statistical analysis

The variables of the years 1912 and 1913 were defined as a baseline in order to compare the following years and examine temporal trends during the observed time period (1912 – 1923). This was further a means to replicate earlier findings, where birth weight alone was analyzed [33]. To compare the different anthropometric parameters for neonatal health, the continuous responses and co-factors were standardized using z-scores. Consequently, all results are given in standardized regression coefficients. Linear regression models were used to estimate the effect of the year for each neonatal health response. Except for the model for GA, where GA is used as response and all GAs are included, we adjusted for age of the mother, height of the mother, SEP, parity, GA (restricted to weeks  $\geq 37$ ) and sex of the child. For the evaluation of fetal death at any gestational age (from here on short: fetal loss) and preterm birth rates, we calculated point estimates of published data of the city of Basel [60] and of the canton Basel [61], which were compared with confidence intervals calculated from our own dataset. All statistical analyses were performed using R Version 3.6.0. The R package “mice” [62] was used to impute the missing data. We used ggplot2 [63] to produce all figures.

### 3. Results

Our initial sample was  $n = 4075$  births, we excluded  $n = 357$  (8.76 %) births. Mothers below the age of 20 years  $n = 81$  (1.99%) and  $\leq 130$  cm  $n = 3$  (0.07 %) were excluded from the sample, as well as twins  $n = 104$  (4.02 %). We also excluded  $n = 1$  neonate with an implausible Ponderal Index  $> 100$  gr/cm<sup>3</sup> (0.03%). All fetal loss  $n = 164$  (4.02 %) were excluded (this aspect of neonatal health was examined separately in Figure 2). Additionally, we excluded births with a gestational age of  $\geq 50$  weeks  $n = 4$  (0.10 %), as they were considered biologically implausible values. For the analysis of gestational age (GA) we used a final sample of  $n = 3'718$ . For the analysis of neonatal measures we further excluded  $n = 228$  (6.13%) preterm births (gestational age  $< 37$  weeks), which led to a final sample of  $n = 3'490$  consisting of live term births from singleton pregnancies from mothers giving birth in the maternity hospital of the city of Basle January 1912 and December 1923. Of these mothers, 86 % were residences of the city of Basel, 7 % lived in the canton Basel Landschaft and the rest came from adjacent areas (other Swiss cantons, Germany or France).

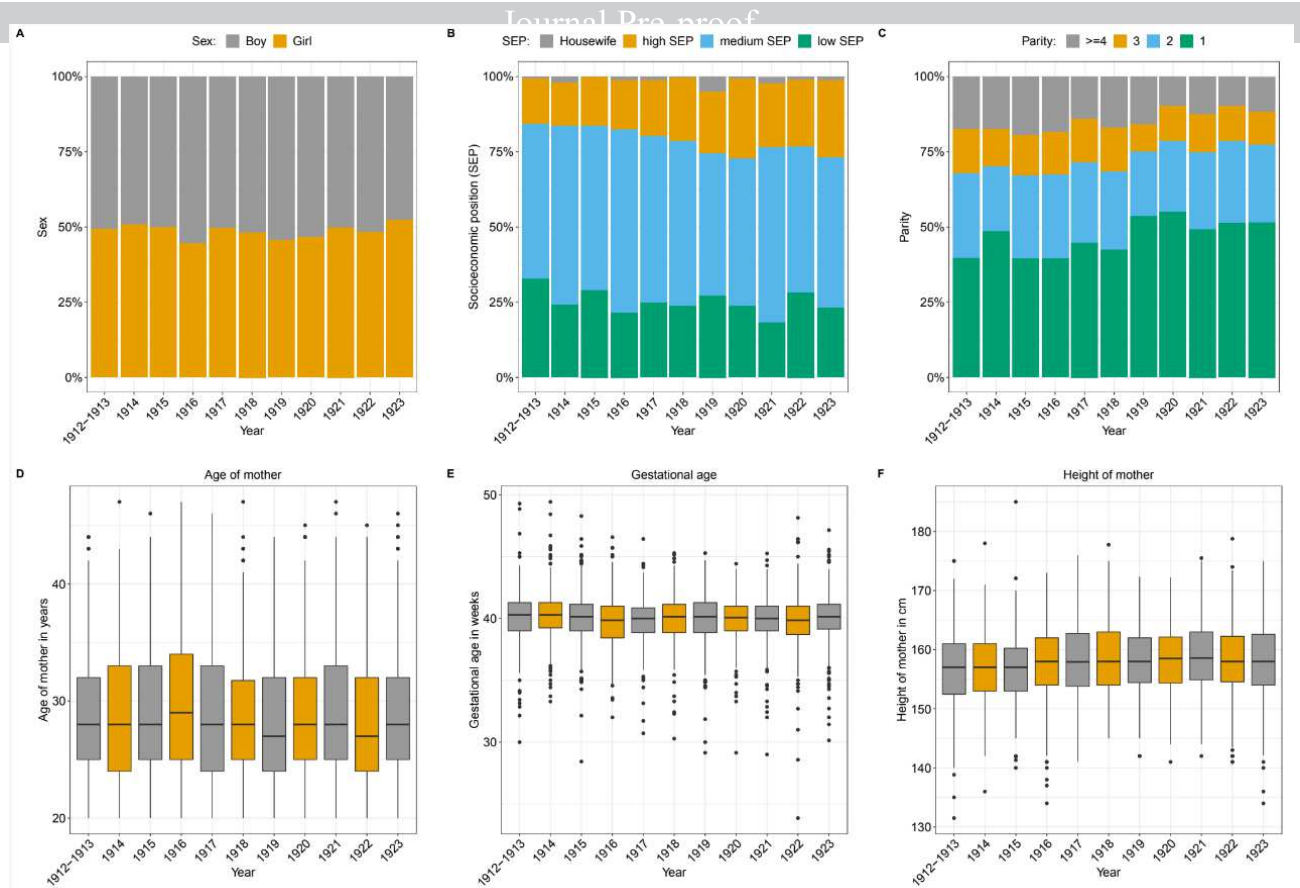


Figure 1: Changes in the sample composition ( $n = 3,718$ ) of newborn sex, family socioeconomic position (SEP), and parity (A-C, upper line) as well as boxplots of maternal age, gestational age (for all gestational ages), and maternal height (D-F, bottom line) across the observation period 1912-1923.

Descriptive statistics of BW, GA (for all gestational ages), PW, PI etc. are presented in Appendix Table 1. The corresponding distributions appear symmetrically (Appendix Figure 1). Figure 1 shows the sample composition and descriptive statistics of selected variables across the years between 1912-1923. During this time period, the proportion of male and female births did not vary considerably (Figure 1A). Maternal characteristics such as mean height and weight (Figures 1D-F) present themselves in a temporally consistent form, as well as gestational age at birth. However, a tendency toward a higher percentage of mothers belonging to a high SEP is visible during the observed time period (Figure 1B). Another tendency concurring with the time period is the shift towards more mothers giving birth for the first time (Figure 1C).

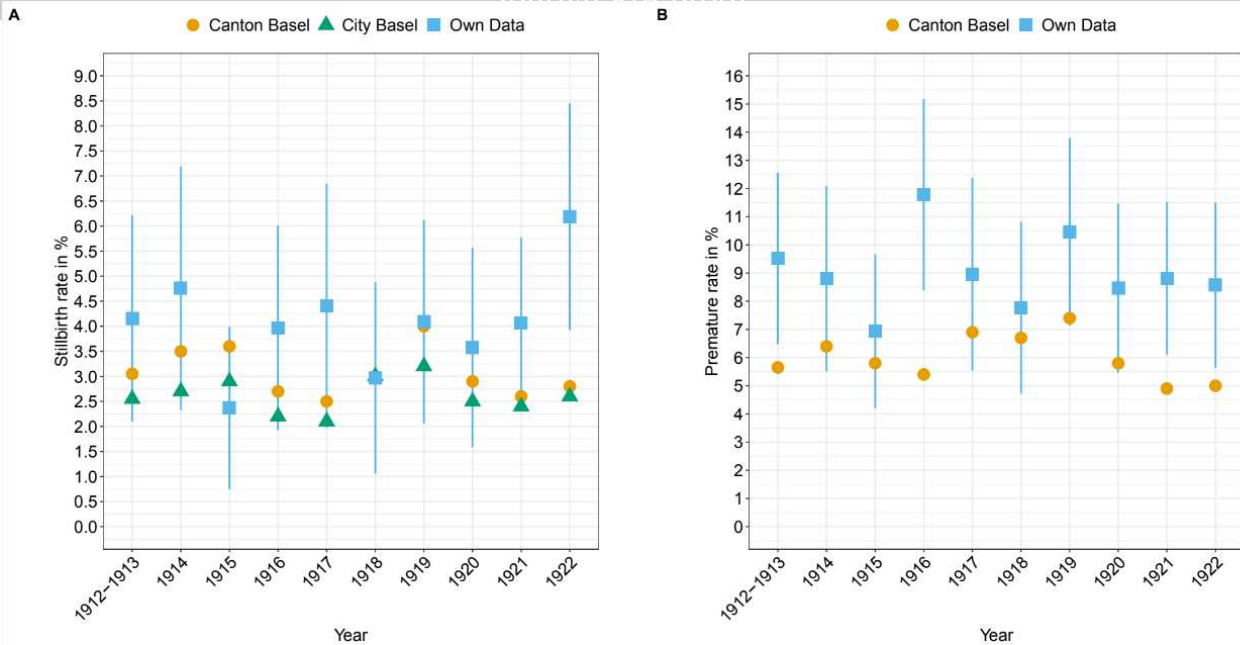
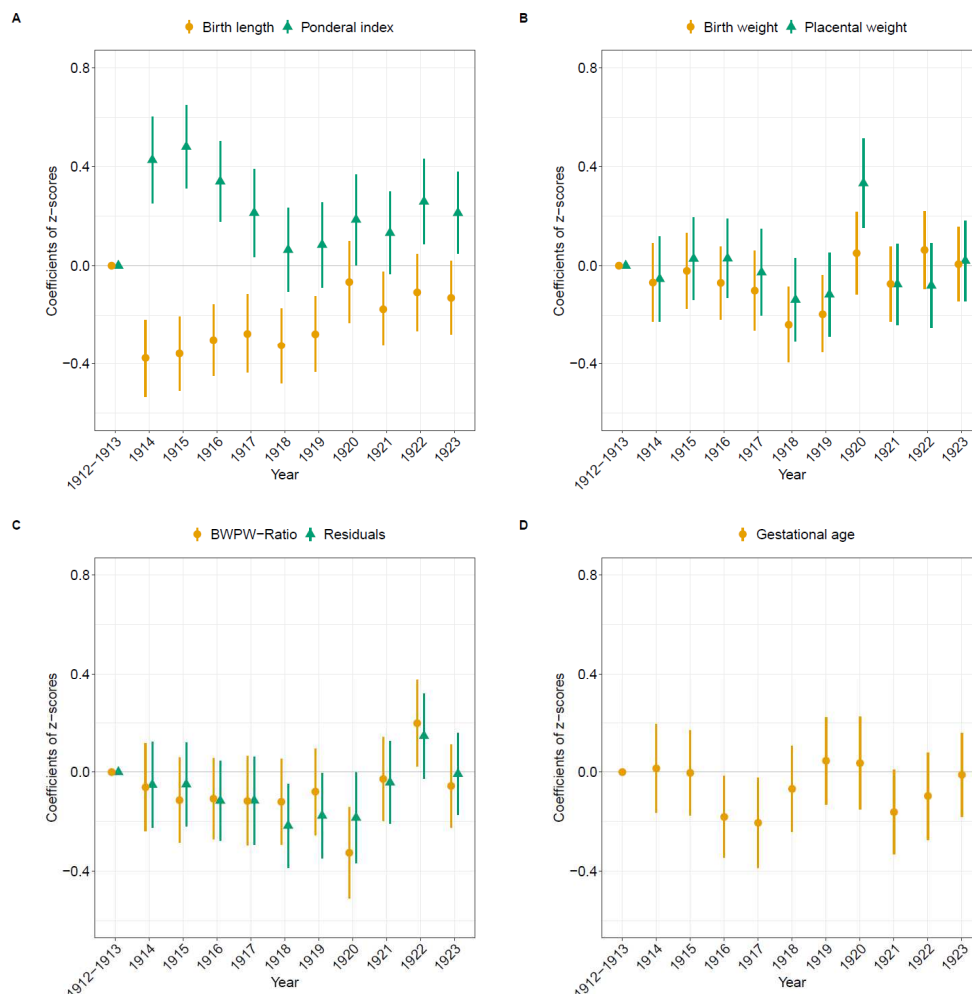


Figure 2: Fetal loss (A, left) and premature birth (as defined at < 32 weeks by the published data) [60] (B, right) rate. The blue squares with 95% confidence intervals indicate the individual data analyzed in this paper ( $n = 3'718$ ), the red and green points/triangles represent published aggregated statistics for the canton and the city of Basel.

Figure 2 shows in blue squares (incl. 95% CI) the crude percentage of fetal loss (A) and the crude percentage of premature rate (B) of all births in our data for each year respectively. This data was compared with published data from the entire canton respectively the entire city of Basel (red points and green triangles). As in the data from the city of Basel preterm birth was defined at < 32 weeks, the other datasets were modeled accordingly. Both Figures (2A + 2B) clearly show that the fetal loss and premature rates of our data are consistently higher than the rates of both of the official data (which cover all births), except in 1915 (A). While the published data series each show a slight peak in 1919, this picture is not so pronounced in the individual data from the maternity hospital analyzed here. The majority of fetal loss occurred after the 20<sup>th</sup> week of gestation (82.3 %).

The results of adjusted linear regressions for BL and PI (Figure 3A, left), BW and PW (3B, right), BW/PW ratio and residuals from PW of BW regression (3C, left), and GA (3D, right) are shown in Figure 3 (detailed results are presented in Appendix Table 1). From the beginning of World War I in 1914 to the after its end in 1919, BL of term births is significantly lower than the baseline values of 1912-1913, however it then remains stable until the end of the observation period (A). As PI is a proportionality parameter and BL is the denominator of the proportion, these two variables develop dependently. PI is significantly higher than the baseline during the war, shows a declining trend during the period of war, with local minima in 1918 and 1919.



244

245 *Figure 3: Coefficient plots showing the fully adjusted linear regressions for birth length (BL) and ponderal*  
 246 *index (A, left), birth weight and placenta weight (B, right), birth weight to placental weight ratio and*  
 247 *residuals from placental weight to birth weight regressions (C, left) among term births ( $n = 3'490$ ), and*  
 248 *gestational age (GA) (D, right) among all included births ( $n = 3'718$ ).*

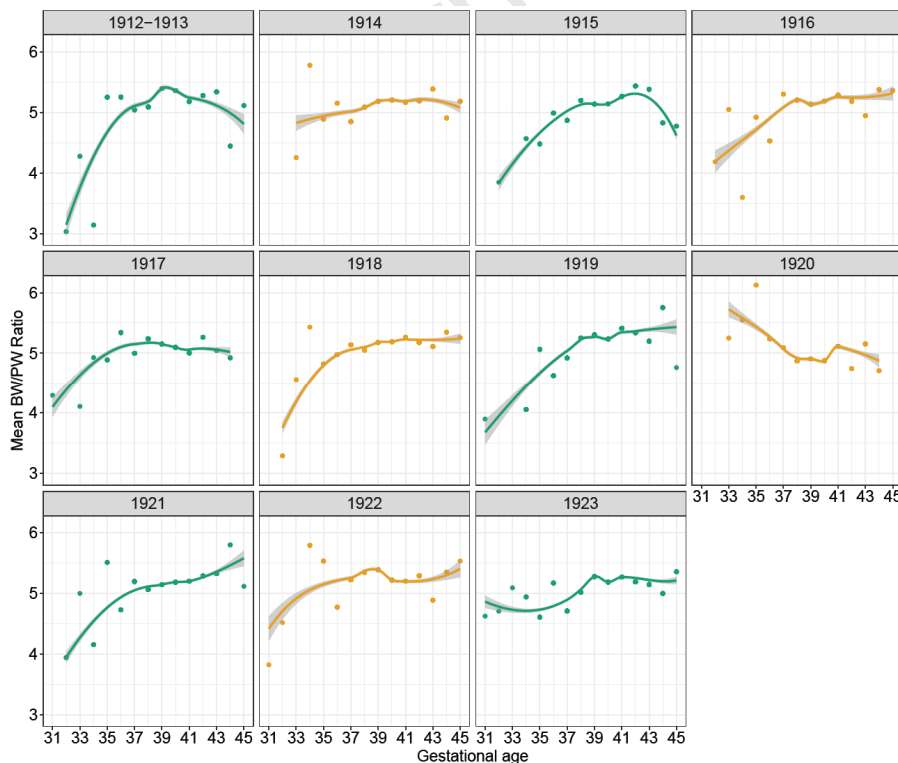
249

250 BW of term births shows a significant dip towards the end of the war in 1918 and 1919 in  
 251 comparison to 1912-13, varying only little before and after those two years (B). PW shows a slight  
 252 but not significant tendency toward lower measurements during the war compared to the baseline of  
 253 1912-13. The lower tendency is especially visible in 1918 and 1919, correlating with our findings of  
 254 lower BWs during those two years as well. However, clearly elevated PWs were found in 1920. In  
 255 terms of the co-factors included in the regressions, higher SEP, higher maternal age, higher  
 256 maternal height, higher parity, higher gestational age, and newborn sex were significantly  
 257 associated with higher BW, BL and PW.

258

259 Similar temporal fluctuations as for PWs are reciprocated in the BW/PW ratios and in the residuals  
 260 of BW and PW regressions (3C). However, a discord between ratios and residuals in reaction to

fluctuations of BWs and PWs was observed in 1918 and 1920. While in 1918 PWs are low (but not significantly lower in relation to our baseline), BWs are significantly lower than expected for the measured PWs, reflected in significantly lower residuals of that year. Contrarily, ratios did not significantly change in respect to the baseline, BWs not being low enough to affect the ratio. In the year 1920, PWs were significantly higher with regard to the baseline, however BWs were as to be expected based on the regression, reflected in the residuals (Appendix Figure 3), as they show no significant deviation to the baseline. The ratio, on the other hand, shows significantly lower values, as the large placental weights lead to a rather large denominator, generating a low ratio. Gestational age (3D) presents an oscillating development around the baseline 1912-1913, with minima in 1915 and 1916, corresponding with increased preterm (Figure 2, B) and fetal loss rates (Figure 2, A). As a first sensitivity check we stratified the regressions from Figure 3 by sex of the neonates. The results (Appendix Figure 4) reveal that the significant associations in the overall models (which are controlled for sex) were more driven by the male neonates. Although girls show the same general tendencies and directions, associations between years and neonatal measures were weaker in girls than in boys. As a second sensitivity analysis, we reran our main regressions as linear random effect models to control for the variance within and between the months of birth (in order to check if the selection of the archived books influenced our results) and found similar patterns (Appendix Figure 5).



**Figure 4:** Mean BW/PW ratio by gestational age (week 31 – 45) and observational year ( $n=3718$ ). The line indicate LOESS smoothing lines, the colors alternate to make the graphic easier to read.



In Figure 4, we expanded our study sample from term births to all births delivered between weeks 30 and 45 and plotted average BW/PW ratio per week of gestational age for each year of observation separately. Until ca. week 38 we see a marked increase in average BW/PW ratio per increasing week of gestation. This means that over these early gestational weeks (31-38), birthweight catches up with placenta weight. Whereas all observational years show this same pattern, 1920 is an exception: Placenta weight was lower in earlier gestational weeks as compared to other years, leading to a higher BW/PW ratio already at earlier gestational periods.

#### 4. Discussion

In the present study, the influence of the first World War on anthropometric parameters of neonatal health in the city of Basel was examined. While during the first half of the war shortages in food supplies could be evaded through sufficient imports, the following years of 1917 and 1918 were marked by harvest failures and a decline in imports causing a food crisis, as well as lower wages and higher prices leading to an impoverishment of the population [34]. The outbreak of the Spanish flu in 1918 presented an additional burden. Our findings mirror these detrimental conditions, as the lowest term BWs and PWs over the observed time period (1912 – 1923) were presented in the years 1918 and 1919.

We have successfully replicated the BW results of one of our previous studies on the benefits of interventions in Basel during World War 1 [33]. Recent studies have indicated a correlation between lower birth weights and economic crises [28, 29], notably mothers of low-educational backgrounds suffered both from nutritional deprivation and maternal stress [29]. Mothers during World War 1 similarly had restricted access to nutritional goods and/or were quite likely subjected to stress caused by various causes (a factor that itself has been shown to be associated with suppressed fetal growth) [25]. Further, PW is known to correlate with BW [9, 39]. Our results show similar tendencies as were found during the Dutch Famine (1944 – 45), where mean PWs declined in a congruent manner to BW, indicating that mothers suffering from malnutrition during third trimester tended to have newborns with lower BWs and PWs [39]. This finding is also consistent with previous research in the field, illustrating the strong relationship between placental and fetal weight under all nutritional conditions, and that while caloric intake is known to influence placental and fetal growth only under severe nutritional deprivation, a lesser direct influence of nutrients on fetal growth is possible [64]. In addition, modern data from Saudi Arabia over ten years has

confirmed that placenta weight may serve as a sensitive indicator reflecting changes in the maternal body composition as a result of changing eating habits during Ramadan [47].

Birth lengths remained low from 1914 - 1919, while PI measurements show a declining trend during the war. Low PI has been indicated to correlate with the mothers diet in pregnancy, mediated through constraints in placental development [65]. While the temporal development of placental weight shows similarities with the temporal development of PI, fluctuations in PI may have also been caused by measuring and reporting biases of BL, as this parameter had been related to low reproducibility [3].

Further, our analysis suggests that the modification of the parameters at birth were not mediated by duration of gestation, as a) our main analysis was restricted to term births only, and b) gestational age deviated from pre-war durations only slightly during the first half of the war, and remained unchanged for the rest of the observed time period. This finding is also consistent with previous statements of length of gestation not being affected by nutritional conditions of the mother, indicating that the modified dimensions of the newborn at birth are not mediated through gestational age and that determinants of gestational age duration differ from those of neonatal anthropometric parameters [3, 66, 67].

While only live term ( $\geq 37$  weeks) parameters of newborns were analyzed, dimensional effects of fetal loss and preterm birth rates were evaluated separately. The rates showed a temporally rather consistent form, the officially published data of the entire canton and the city of Basel showing a slight peak in 1919 - this trend being less pronounced in the individual data from the maternity hospital. In general, the rate of fetal loss and premature births in the maternity hospital were slightly higher than in published figures for the entire canton. It must remain unclear whether this could point towards a selection bias (i.e., more complicated pregnancies and births in the hospital) and/or underreporting of fetal loss delivered at home. While low placenta weight has been indicated as a risk factor of stillbirth [68], the relationship remains unknown, and while comparatively lower placenta weights were found in 1919, a causal connection could not be made.

With the intention of examining the correlation between birth weights and placenta weights, a rather remarkable finding was reached by direct comparison of variations in BW/PW ratio and residuals from regression of PW to BW. In 1918, birth weights were lower than expected for the measured placental weights, reflected in significantly lower residuals. According to current theory, where ratio is used as a proxy for placental efficiency [13, 69], our findings would imply a reduced



placental efficiency, however ratios are not significantly lower in comparison to the baseline.

Furthermore, low ratios were found in 1920, in response to high placental weights, indicating a reduction in placental efficiency of that year. However, residuals in 1920 did not significantly deviate from the baseline i.e. birth weights were as to be expected for the given placental weights, implying that placental efficiency did not lessen in comparison to the baseline.

Our analysis confirms Christians et. al. [51] conclusion that ratios are subjected to undesirable properties, as changes in BW/PW ratio are a result of the intercept not being zero, thus creating an artefact. Instead, the use of residuals as a measure of placental efficiency is proposed, and our findings support this suggestion. Furthermore Hayward et.al. called attention to the fact that the ratio alone only offers limited insight into placental efficiency, therefore considering if it is the weight of the fetus or the placenta that is higher or lower than the norm is crucial, and offers greater insight into the probability of incidence of abnormal placental function [13]. Another remarkable finding was the high placental weights recorded during the year of 1920. As records stating the exact protocols of measurements could not be found in the archives, it is possible that the high measures are the result of a measurement and/or reporting bias (e.g. method of measurement or change of scales). However, the high measurement may also be an expression of compensatory effect of the placenta due to the low birth weights in the years before. In order to examine this hypothesis a larger basis would be necessary.

There are some limitations to this study. Firstly, birth records are not complete for each year (only one third of the original records were available, and our data represents only about 20% of all births given in the maternity hospital at that time), suggesting our study could be subject to a selection bias as the births may have been influenced by other factors not included in this study, e.g. seasonal influences. As a sensitivity analysis, we reran our main regressions as linear random effect models to control for the variance within and between the months of birth and found similar patterns. For that reason, we assume that the month of birth, and thus the selection of the book, did at least not vastly influence our results. Secondly, the specific methods of measurement could not be traced in other documents of the archives, as for the comparison of our data with further studies it would be relevant to know how birth weight or placenta weight were measured (if the placenta was weighed trimmed or untrimmed [10, 70]). Specifically information on the methods of measurement may have made it possible for us to explain the unusual placenta weight data we collected for the year 1920. Thirdly, direct measures of maternal nutrition intake and stress would be insightful for a deeper understanding of their effects on neonatal anthropometric parameters. Fourthly, we were unable to isolate the effects of war versus the effects of infection from the Spanish flu, which hit

Basel from early July 1918. Since our archival source for the year 1918 covers only births that took place before May, these pregnancies and births cannot have been influenced by the Spanish flu. However, for births in 1919 (coverage from March), there is a possibility that infection may have taken place during pregnancy (in Basel, the second wave occurred between October 1918 and January 1919). Unfortunately, the qualitative medical histories in the archival source of the maternity hospital have not been recorded in a standardized way enough to be able to control this on an individual level.

## Conclusion

Our study provides first direct evidence of changes in anthropometric parameters for neonates born during the World War 1 in the city of Basel. It shows that countries not directly involved in war can nonetheless be affected by political and economic disruptions on a larger scale. Although socioeconomic conditions were not severe enough to cause a famine, detrimental effects on neonatal health were nonetheless visible. Low BW and PW measures coincided with the pinnacle years of the war in 1918 and 1919, as also the Spanish flu swept through Basel. Further studies should disentangle war vs. infection effects and test if individuals born during these years may have a slightly higher risk of suffering from chronic disease in adult life [71, 72].

**Acknowledgements**

We are greatly indebted to the archivists of the Staatsarchiv Basel Stadt for their support in accessing the birth registers used in this study. Furthermore, we thank Ulrich Woitek, Frank Rühli, Bernard Harris, Barry Bogin, Peter Ward, Eric Schneider, Sarah Gang, Lars Mehr, Tim Cole, Jonathan Wells, Marek Brabec, Nikola Koepke, and Martin Häusler for previous collaborations and/or helpful comments.

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## Highlights

- A retrospective analysis of term births in the maternity hospital of Basel from 1912 to 1923 was conducted.
- Birth weights, placenta weights and residuals were at their lowest at the end of the war in 1918/19.
- Populations in neutral zones during wars can be afflicted as well, posing a great health burden on mothers and newborns.



**Competing interest:** The authors declare no conflicts of interest.

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